High-Temperature Steam Electrolysis for Hydrogen Production

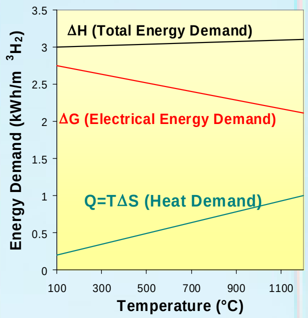
Materials Development for Improved Efficiency and Durability

Jennifer Mawdsley, Deborah Myers, and Xiaoping Wang
Electrochemical Technology Program, Chemical Engineering Division, Argonne National Laboratory

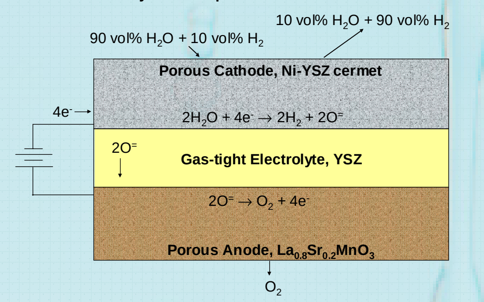
Introduction

High-temperature steam electrolysis using heat and electricity from a nuclear reactor is a route to making affordable hydrogen. This process splits water with heat and electrical energy using the technology of solid oxide fuel cells (SOFC), where:

- The cell is polarized to reverse the SOFC reaction
- The feed stream is 90% steam/10% hydrogen
- Operating between 700°C and 900°C reduces the electrical energy demand



Solid Oxide Electrolyzer Cell Operation:



Challenges

- A much more active oxygen evolution electrode material is needed.
- The traditional SOFC has been optimized for performance at 1000°C. The oxygen electrode material of the traditional SOFC, $La_{0.8}Sr_{0.2}MnO_3$ (LSM), has limited oxygen ion and electronic conductivity at temperatures between 700°C and 900°C.

Approach

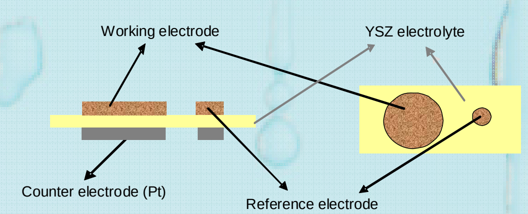
We have been investigating alternative materials for improved oxygen electrode performance below 1000ºC by exploring materials with significant electronic and ionic conductivity at 800 to 900°C, such as:

- $LaNiO_3$ (LN)
- $La_{0.8}Sr_{0.2}CoO_3$ (LSC)
- $La_{0.8}Sr_{0.2}FeO_3$ (LSF)
- $La_{0.7}Sr_{0.2}FeO_3$ (LSF-ns)

Experimental procedure:

- Powders of the electrode materials were synthesized using a self-combustion process
- Electrode inks were made by ball milling the powders with ethanol
- The electrode inks were painted onto yttria-stabilized zirconia (YSZ) subtrates to make the working and reference electrodes
- Counter electrodes were painted onto the opposite sides of the YSZ substrates using platinum ink
- Electrochemical impedance spectroscopy (EIS) was used to evaluate the electrode materials' area specific resistance (ASR) at temperatures of 800, 850, 900, and 1000°C

Sample Geometry for Impedance Spectroscopy:



Results and Conclusions

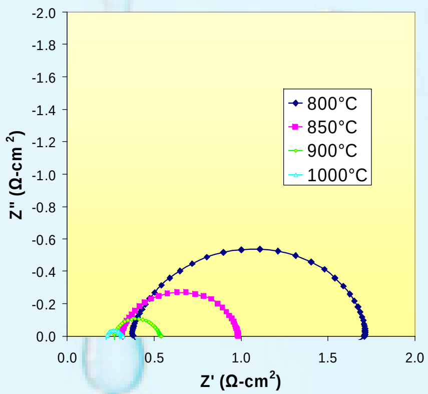
- Our results have shown that LSC and LSF-ns have lower ASR's than commercially available LSM-based materials at temperatures between 800°C and 900°C.
- EIS results are shown in the form of a Nyquist plot—real impedance, Z', versus imaginary impedance, Z".
- ASR is calculated using the following equation:

$$ASR = Z'_{max} - Z'_{min}$$

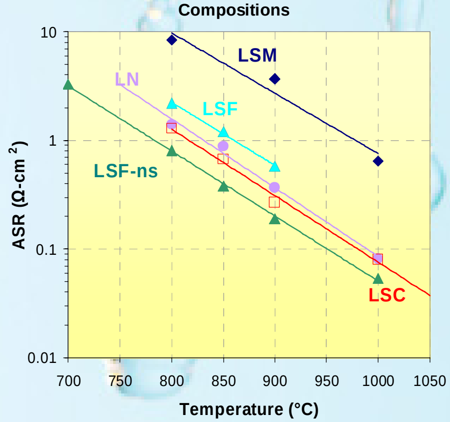
Electrode Composition	Area Specific Resistance (Ω-cm²)			
	800ºC	850ºC	900ºC	1000ºC
$La_{0.8}Sr_{0.2}MnO_3$	8.4	nd	3.7	0.65
$La_{0.8}Sr_{0.2}CoO_3$	1.3	0.67	0.27	0.080
$La_{0.8}Sr_{0.2}FeO_3$	2.2	1.2	0.58	nd
$La_{0.7}Sr_{0.2}FeO_3$	0.81	0.38	0.19	0.054
$LaNiO_3$	1.4	0.89	0.37	0.082

nd = not determined

Nyquist Plots for $La_{0.8}Sr_{0.2}CoO_3$



Arrhenius Plot for All Electrode Compositions



Research funded by the U.S. Department of Energy, Office of Nuclear Energy, Science and Technology